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MIPR-NO. 1.01182
AMCMS Code: 5910.21.63389
HDL Proj. No. E01E4

HDL-TM-72-5

# THE USE OF FIBER OPTICS FOR OSCILLOSCOPE EXTERNAL TRIGGERING

by

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April 1972

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U.S. ARMY MATERIEL COMMAND
HARRY DIAMOND LABORATORIES
WASHINGTON, D.C. 20438

UNCLASSIFIED
Security Classification

# DOCUMENT CONTROL DATA - R & D

*(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)*

| | |
|---|---|
| 1. ORIGINATING ACTIVITY (Corporate author) Harry Diamond Laboratories Washington, D.C. 20438 | 2a. REPORT SECURITY CLASSIFICATION Unclassified |
| | 2b. GROUP |

3. REPORT TITLE

THE USE OF FIBER OPTICS FOR OSCILLOSCOPE EXTERNAL TRIGGERING

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

Rudolph J. Prochazka

| 6. REPORT DATE | 7a. TOTAL NO. OF PAGES | 7b. NO. OF REFS |
|---|---|---|
| April 1972 | 18 | 0 |

| | |
|---|---|
| 8a. CONTRACT OR GRANT NO. | 9a. ORIGINATOR'S REPORT NUMBER(S) |
| b. PROJECT NO. MIPR-NO. 1.01182 | HDL-TM-72-5 |
| c. AMCMS Code: 5910.21.63389 | 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) |
| d. HDL Proj: E01E4 | |

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

| 11. SUPPLEMENTARY NOTES | 12. SPONSORING MILITARY ACTIVITY |
|---|---|
| | SAFSCOM |

13. ABSTRACT

The input to the external trigger circuit of an oscilloscope is normally designed to accept a remotely generated trigger signal via coaxial cable. A photodiode was installed in the input so that it accepts an optical trigger signal via a fiber optic cable. This inexpensive conversion is useful in electromagnetic interference (EMI) studies, where hard wire cables can contaminate shielded environments, and does not interfere with the oscilloscope's other triggering capabilities. The original input can be restored at any time, in the field or in the laboratory.

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

UNCLASSIFIED
Security Classification

| 14. KEY WORDS | LINK A | | LINK B | | LINK C | |
|---|---|---|---|---|---|---|
| | ROLE | WT | ROLE | WT | ROLE | WT |
| Fiber optics | 8 | 3 | | | | |
| Oscilloscope | 8 | 3 | | | | |
| External trigger | 8 | 3 | | | | |

## ABSTRACT

The input to the external trigger circuit of an oscilloscope is normally designed to accept a remotely generated trigger signal via coaxial cable. A photodiode was installed in the input so that it accepts an optical trigger signal via a fiber optic cable. This inexpensive conversion is useful in electromagnetic interference (EMI) studies, where hard wire cables can contaminate shielded environments, and does not interfere with the oscilloscope's other triggering capabilities. The original input can be restored at any time, in the field or in the laboratory.

<u>CONTENTS</u>



<u>FIGURES</u>

## 1. INTRODUCTION

One of the most frequently used instruments in electromagnetic interference (EMI) studies is the oscilloscope. Great emphasis is directed toward minimizing spurious signals on data channels and constructing leak-proof enclosures for these oscilloscopes. Within this environment, bringing in an external trigger signal on a hard-wire cable could contaminate the enclosure with electromagnetic radiation. This problem can be eliminated by using a fiber optic cable that terminates at a photodiode inside the oscilloscope, providing a light-activated, electrically isolated trigger.

As an inexpensive modification to the oscilloscope's external trigger input, the conversion only requires the installation of a photodiode mounted inside a specially designed fixture that is mounted as an assembled unit within the oscilloscope. The only exposed portion is the receptacle for the fiber optic (light pipe) cable. The installed fixture is shown in figure 1.

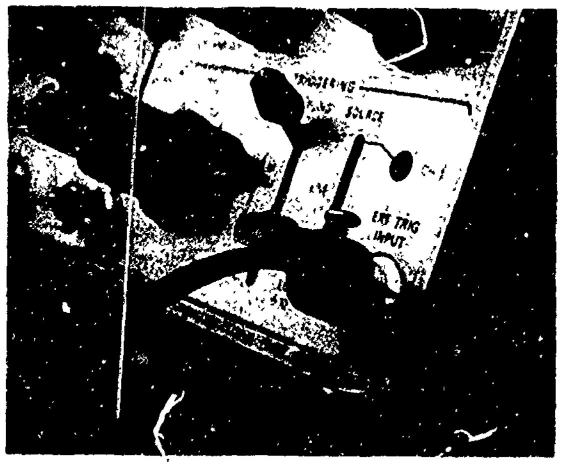


Figure 1. Oscilloscope showing completed modification.

## 2. ELECTRICAL DESIGN CONSIDERATIONS

In all *PIN* silicon photodiodes, there is a capacitance associated with a *PIN* junction. This junction capacitance ($C_j$), combined with an external load resistance ($R_L$), will determine the diode's response time (RC). Ideally, this response time can be adjusted only by properly selecting $R_L$, since $C_j$ is limited to a fixed value determined by the bias voltage. Furthermore, a compromise must be made between a fast response time (small $R_L$) and a high sensitivity (large $R_L$). Therefore, $R_L$ is a variable controlling the diode's response time/sensitivity characteristics.

For this design, $R_L$ is introduced by the external trigger impedance, which can either be high (1 MΩ) or low (50 Ω) depending on the manufacturer. A properly triggered oscilloscope will display the leading edge of the waveform and a portion of the base line as a reference. To achieve this, the trigger signal must be capable of producing a certain voltage excrusion within a predetermined time frame as indicated in figure 2.

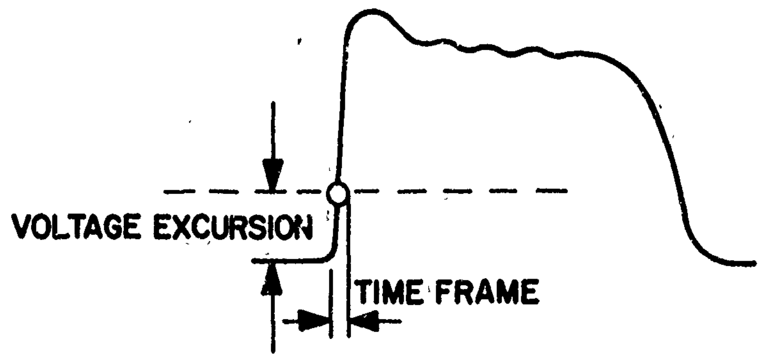


Figure 2. Characteristics of a trigger signal.

Generally, the steepest portion of the trigger waveform will provide the most stable triggering. The diode's output can serve as a source for a trigger signal, since the risetime (response time) is actually a voltage excursion occurring within the time frame of a pulse.

Consider the simplified equivalent circuit for a photodiode shown in figure 3. In the photoconductive mode, the diode acts as a current generator and will continue to deliver the same amount of signal current into any load from a constant light source. (The signal current parameter is measured in mA/mW at a specific wavelength and is usually identified as sensitivity or responsitivity.) However, as the incident light level is increased, current increases linearly until the saturation current limits are approached. The junction capacitance($C_j$) of the diode is voltage dependent and decreases with increasing bias voltage. In a high-impedance oscilloscope, the existence of a large $R_L$ is not realized at high frequencies due to the low reactance ($X_C$) introduced by $C_j$. This behavior is analogous to a low-pass filter. Since the signal voltage will eventually be influenced by $R_L$, the diode's output characteristics, in conjunction with $R_L$, will be a signal with a slow response (long risetime), as shown in figure 4.

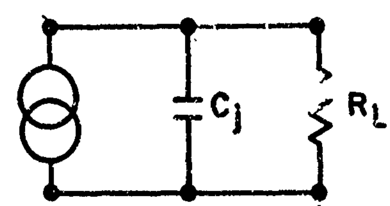


Figure 3. Equivalent circuit for a photodiode.

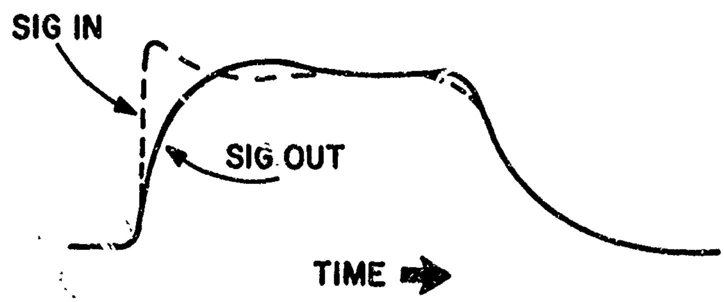


Figure 4. A long risetime caused by $R_L$.

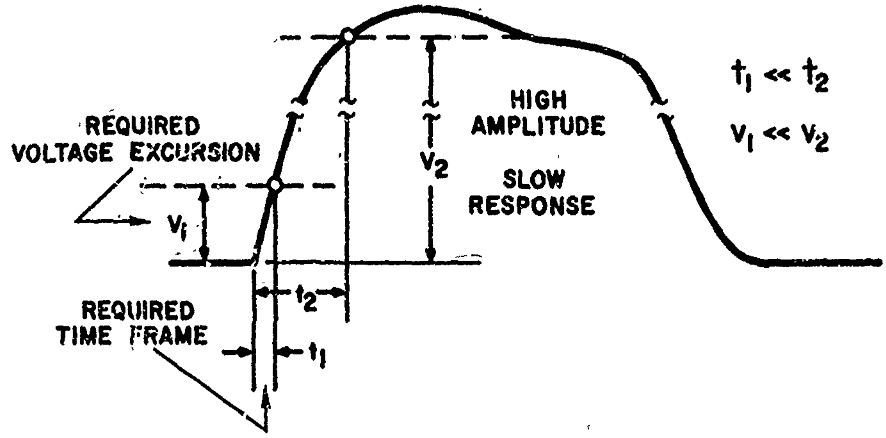


Figure 5. Diode's output with a large $R_L$.

In figure 5, the signal appears to be rising rapidly at early times. The required voltage excursion (for oscilloscopes with high impedance, 400mV, less at lower frequencies) can be obtained from this small portion of the total signal amplitude without being seriously affected by the overall slow response characteristics.

The existence of a small $R_L$ can be tolerated, since most oscilloscopes with a low trigger input impedance require a low trigger signal level (<40mV, DC to 250MHz).

## 3. THE MODIFICATION

As illustrated in figure 1, external hard wire connections are not necessary, because the load resistor, $R_L$, and bias voltage are available internally. The bias voltage and load resistor are located on the "A" *TRIGGER GENERATOR* circuit board. $R_L$ is actually the input resistance, R615, for V623, shown in figure 6.

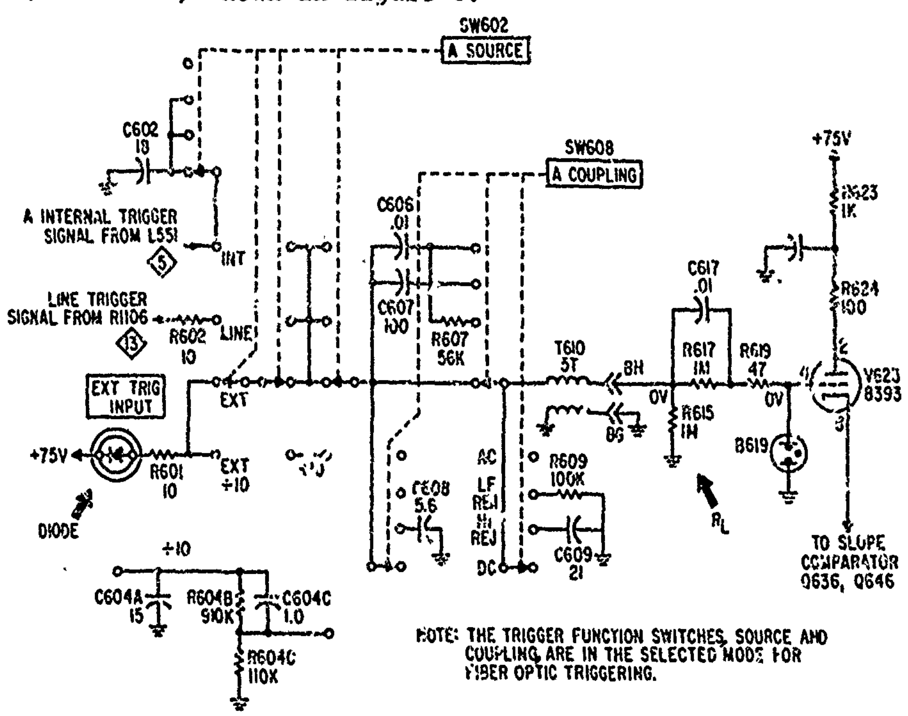


Figure 6. Oscilloscope external trigger circuit; modified electrical diagram. (Courtesy of Tektronix, Inc.)

The bias supply voltage for the photodiode can be obtained from the distributed power supply voltages available within the oscilloscope. Its magnitude will dictate the operating parameters (leakage current, junction capacitance, and the breakdown voltage) of the selected diode. The location of the photodiode, shown in figure 7, is labeled *EXT TRIG INPUT*. Using the input impedance as $R_L$, the diode is connected to the external trigger circuit as shown in figure 6 without altering the normal triggering operation of the oscilloscopes. The diode will not reduce the performance of the oscilloscope's trigger functions (i.e., *TRIGGER SOURCE*, *TRIGGER COUPLING* or *TRIGGER MODE*) and is decoupled from the trigger circuits when external triggering *is not* selected.

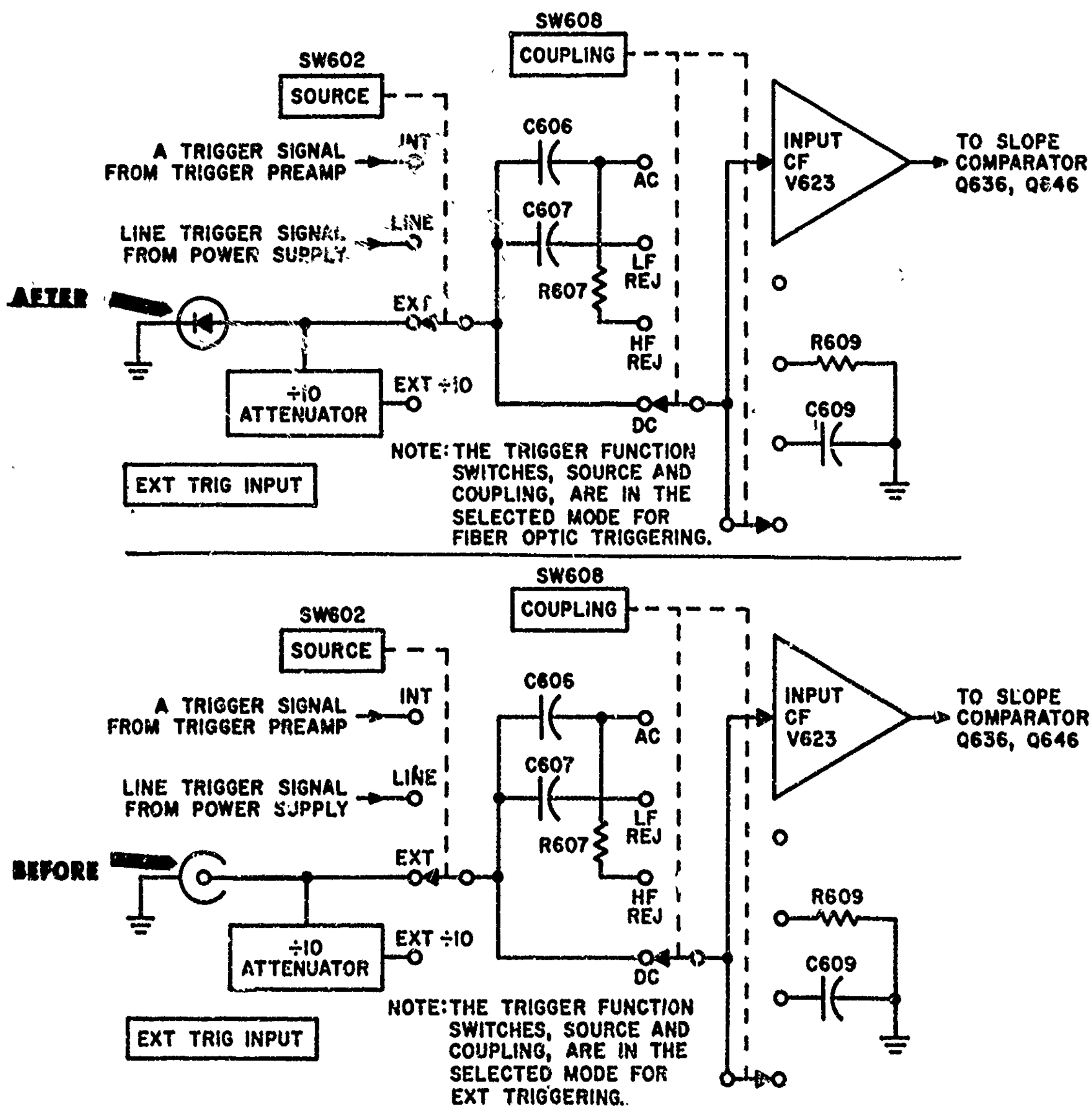


Figure 7. Oscilloscope external trigger circuit; block diagram for diode location. (Courtesy of Tektronix, Inc.)

The diode is installed in a special diode fixture fabricated from a BNC UG657/U chassis-type connector. The fixture is shown disassembled in figure 8. The insert is made of a nonmetallic material to isolate the anode (or cathode) electrically from ground. Most diodes will have the anode or cathode grounded to the case. A common cathode configuration (negative bias) can be used to provide a negative trigger signal. The insert is also used as a coupler for the light pipe and diode. Also shown in figure 8 is a locking nut, used to hold the diode firmly within the fixture. The engineering drawings in figure 9 are examples of how the fixture may be constructed; the assembly of the diode fixture is illustrated in figures 10 and 11.

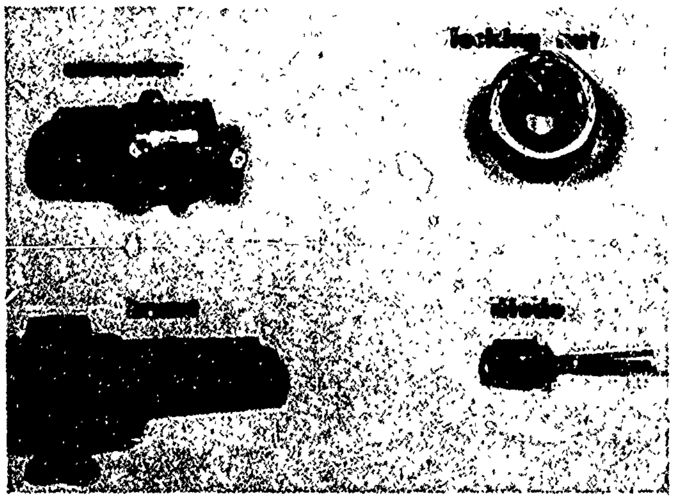

Figure 8. Diode fixture disassembled.

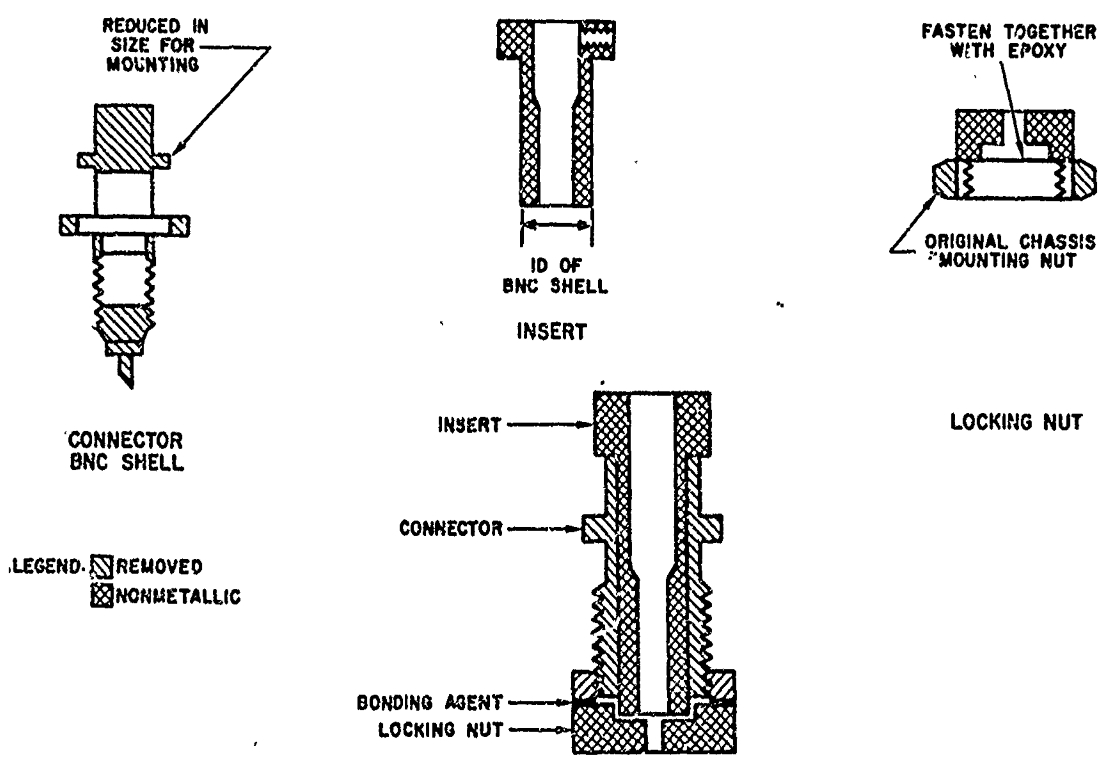


Figure 9. Component parts of diode fixture.

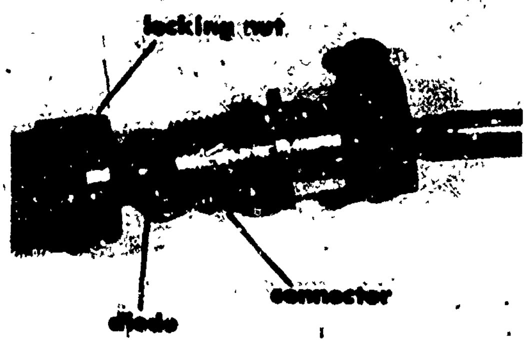


Figure 10. Component alignment for diode fixture.

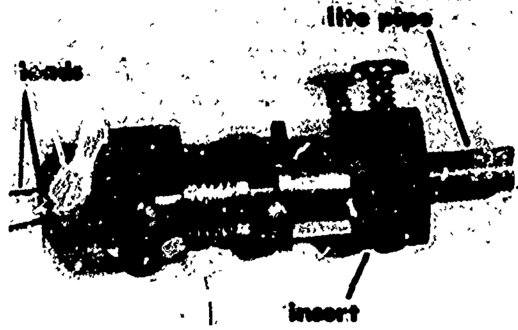


Figure 11. Assembled diode fixture.

Modification of the oscilloscope required the removal of only one piece of hardware, the BNC connector J601, shown in figure 6. This connector is retained for later use to restore the oscilloscope to its original condition. R601 (10Ω) is disconnected from J601 and reconnected to the diode's anode. Figure 12 shows the diode fixture installed inside the oscilloscope without the locking nut (diode is visible); figure 13 with the locking nut mounted. In both photographs, the pointer identifies the diode fixture assembly.

Figure 12. Diode fixture mounted inside oscilloscope (no locking nut).

Figure 13. Diode fixture mounted inside oscilloscope (with locking nut).

## 4. CONCLUSIONS

The problem of contamination from spurious signals that exists when triggering an oscilloscope with a hard-wire cable during EMI studies can be eliminated when a fiber optic cable is substituted. An inexpensive modification to the external trigger input of the oscilloscope converts the input into a photosensitive input that will accommodate the fiber optic cable.

Selection of a diode and bias supply voltage appear to be the dominant criteria affecting the diode's performance, since the characteristic effect of using a large $R_L$ does not degrade the diode's function as a source for a trigger signal.